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Final Report for the Local Ionospheric Measurements Satellite (LionSat)

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**6. AUTHOR(S)**
Sven G. Bilén

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Pennsylvania State University
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University Park, PA 16802-1003

**8. PERFORMING ORGANIZATION REPORT NUMBER**
N/A

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**13. ABSTRACT** *(Maximum 200 Words)*

In the Performance Period, the LionSat team has continued development of a nanosatellite as part of the University Nanosat 3 Program. The team has participated in several NS-3 sponsored events/milestones, including the Flight Competition Review. LionSat is a "sciencecraft" with science experiments and bus fully integrated. It will explore the ram/wake structure of a small spacecraft via plasma probes placed on booms that will move in and out of the wake as the nanosatellite "rolls" along its orbit. The plasma measurements of the local ambient as well as ram/wake plasma environments will be made via a novel hybrid plasma probe that will operate in different modes to investigate a broad range of geophysical conditions that occur on various temporal and spatial scales. LionSat will flight test a miniature RF ion thruster (MRIT) by increasing the spin-rate of the spacecraft using a pair of MRITs. Through measuring the increase in spin, the LionSat team will be able to determine thrust levels obtained with the MRIT. LionSat will also employ and test IP communications for uplink and downlink.

Although not selected during the FCR, the LionSat team is continuing satellite development and is pursuing launch opportunities. To date, over 100 students have been involved in some capacity with the LionSat project.

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8-4-05

## Table of Contents

## 1. OBJECTIVES

The Local Ionospheric Measurements Satellite (LionSat) mission provides a breadth of learning experiences for students who are involved in designing, building, and flying Penn State's first student-built satellite [*Mistoco et al.*, 2003]. A key part of LionSat is the educational programming available to students of diverse backgrounds and academic interests. Our educational goal is to prepare students at the undergraduate and graduate levels for productive careers in technical and nontechnical fields relating to space systems and science. The LionSat mission introduces relevant hands-on opportunities to students through design problems, science questions, case studies, research investigations, leadership experiences, organizational issues, etc. LionSat introduces meaningful and realistic project examples into the classroom and laboratory, which enhance student learning.

The LionSat mission was selected as a participant in the Nanosat-3 (NS-3) program, which is a joint program between the American Institute of Aeronautics and Astronautics (AIAA), the National Aeronautics and Space Administration Goddard Space Flight Center (NASA GSFC), the Air Force Office of Scientific Research (AFOSR), and the Air Force Research Labs Space Vehicles Directorate (AFRL/VS). The objectives of the NS-3 program are to educate and train the future workforce through a national student satellite design and fabrication competition and to enable small satellite R&D, payload development, integration, and flight test. Also important to the program is the ability to fly new technologies to prove them out in space.

LionSat is a "sciencecraft" with science experiments and bus fully integrated. LionSat is a spinner that will "roll along" the orbit with the spin axis perpendicular to the orbit plane. It will explore the ram/wake structure of a small spacecraft via plasma probes placed on booms [*Surrusco et al.*, 2004] that will move in and out of the wake as the nanosatellite "rolls" along its orbit. LionSat will obtain ambient measurements of the undisturbed plasma environment and correlate them to the ram/wake measurements. The plasma measurements of the local ambient as well as ram/wake plasma environments will be made via a novel hybrid plasma probe [*Siegel*, 2003] that will operate in different modes to investigate a broad range of geophysical conditions that occur on various temporal and spatial scales. The primary engineering goal of LionSat is to flight test a miniature RF ion thruster (MRIT) by increasing the spin-rate of the spacecraft using a pair of MRITs [*Mistoco et al.*, 2004]. Through measuring the increase in spin, the LionSat team will be able to determine thrust levels obtained with the MRIT. LionSat will also employ and test Internet Protocol (IP) communications for uplink and downlink [*O'Connor et al.*, 2004; *Surrusco et al.*, 2003].

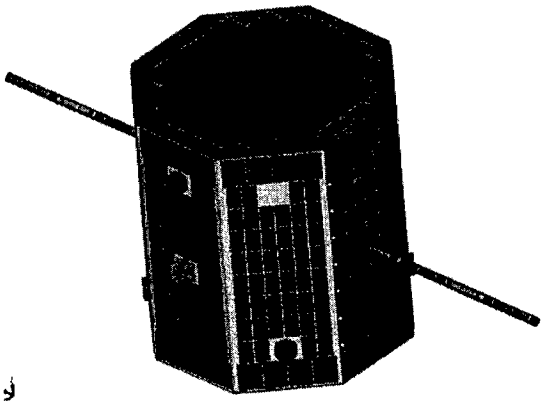


**Figure 1** LionSat with booms extended

LionSat is a multi-disciplinary space systems project involving several departments of The Pennsylvania State University, including electrical, aerospace, and mechanical engineering departments. The project also includes students from the College of Science and the College of Education. The Communications and Space Sciences Laboratory (CSSL), located on campus, is serving as the coordination center for the project. The research conducted by the CSSL is focused on electromagnetics, atmospheric, and ionospheric properties. As a result, this present effort is well integrated with laboratory efforts to understand the ionosphere. Although LionSat's scientific goals are important, the educational objectives are the driving force for the project. Consequently, student involvement in all aspects and at every level is a priority. This project is designed and managed by students with assistance provided by different faculty members assuming mentoring and advising roles

**Figure 2** Students begin assembling LionSat in CSSL's cleanroom facility

## 1.1 Summary of Mission Objectives:

The following mission statement and objectives have been developed for the LionSat mission.

### 1.1.1 Mission Statement

The LionSat mission will investigate the local ambient and perturbed plasma environments surrounding a small satellite in the Earth's ionosphere. LionSat will measure the ambient plasma environment and the satellite's ram and wake regions using a novel hybrid plasma probe instrument. LionSat will test a miniature RF ion thruster system that will augment the satellite spin, which is necessary for mapping the plasma environment surrounding the satellite.

### 1.1.2 Technology Demonstration

LionSat will demonstrate the Hybrid Plasma Probe as a plasma diagnostic instrument. LionSat will also test *in situ* a miniature RF Ion Thruster as a satellite spin control device.

### 1.1.3 Mission Objectives

**Primary Objectives:**

P1. To map the ram and wake plasma structure surrounding a small satellite

P2. To collect data on ionospheric plasma in a variety of geophysically interesting locations in low Earth orbit

P3. To test, on orbit, a miniature RF ion thruster

**Secondary Objective:**

S1. To test IP communications for uplink and downlink to a spacecraft in low Earth orbit

## 1.2 References

Cipollo, P.,* B. S. Surrusco,** and S. G. Bilén, "An electrically actuated pin-puller for space application using nickel–titanium memory alloy," the 18th Annual, AIAA/Utah State University Conference on Small Satellites, 9–12 August 2004.

Mistoco, V. F. M.,** S. G. Bilén, and M. M. Micci, "Development and chamber testing of a miniature radio-frequency ion thruster for microspacecraft," 40th AIAA/ASME/ASEE Joint Propulsion Conference, Ft. Lauderdale, FL, 11–14 July 2004.

Mistoco, V. F., R. D. Siegel,** B. S. Surrusco,* E. Medoza,* and S. G. Bilén, "Design of the Local Ionospheric Measurements Satellite," 17th Annual, AIAA/Utah State University Conference on Small Satellites, 11–14 August 2003.

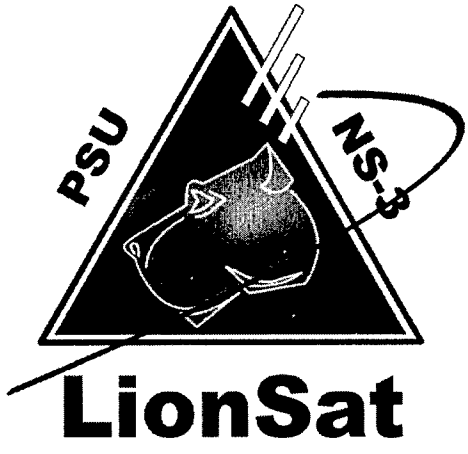
O'Connor, Nathan F.,* Brendan S. Surrusco,** Sven G. Bilén, and Charles L. Croskey, "Software-Defined Radio Ground Station for Internet-Protocol Communications to a Low Earth Orbit Nanosatellite," NASA Fourth Space Internet Workshop, Hanover, MD, 7–9 June 2004.

Siegel, R. D., IV,** *Design of a Hybrid Plasma Probe System*, M.S. Thesis, Electrical Engineering Dept., Penn State Univ., University Park, PA, May 2004.

Surrusco, Brendan,* Robert D. Siegel,** Phillip M. Sorber,* Derek V. Morr,* Nathan F. O'Connor,* Charles L. Croskey, Sven G. Bilén, and Jason A. Soloff, "Mission planning for employing internet protocol (IP) communications on the Local Ionospheric Measurements Satellite (LionSat)," NASA Third Space Internet Workshop, Cleveland, OH, 4–6 June 2003.

** Graduate Student

* Undergraduate Student



## 2. STATUS OF EFFORT

In the Performance Period (1 Sept. 2004–31 Mar. 2005), the LionSat team has continued development of a nanosatellite as part of the University Nanosat 3 Program. The team has participated in several NS-3 sponsored events/milestones, including teleconferences and the Flight Competition Review (Figure 3). Although not selected for flight during the FCR, the LionSat team is continuing to complete the payload and aggressively pursuing other launch opportunities. To date, over 100 students have been involved in some capacity with the LionSat project.

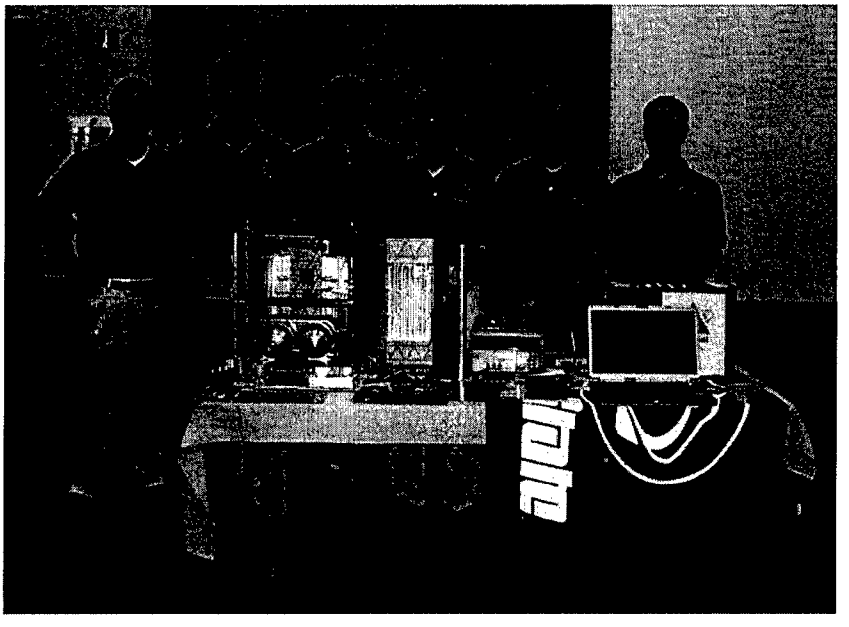


**Figure 3** Students displaying LionSat at the Flight Competition Review

## 3. ACCOMPLISHMENTS/NEW FINDINGS

The current status and design of the LionSat satellite was documented in the Flight Competition Review material, which was presented at the AIAA Aerospace Sciences Meeting in January 2005. The Flight Competition Review presentation material is attached as Appendix A. Other material was made available on the University Nanosatellite web server. A poster with an overview of LionSat's status as of the FCR is provided in Appendix B.

## 4. PERSONNEL SUPPORTED

As the LionSat project is tied to the academic year, student support fluctuates throughout the year. The faculty mentors, who remain on the project, help maintain corporate knowledge. The faculty involved include:

### Faculty Mentors

Dr. Sven G. Bilén (Principal Investigator), Dr. Charles Croskey, Dr. Robert Melton, Dr. David Spencer, Dr. Deborah Levin, and Dr. Michael Micci.

### Students

Since the beginning of the project, the following students (graduate and undergraduate) have participated in the project:

| Name | Citizenship | Student Status | Work terms | Team(s) |
|---|---|---|---|---|
| Adedipe, Ayokunle | U.S.A. | Undergrad | SP05 | Command and Data Handling |
| Amaral, Sergio | U.S.A. | Undergrad | SP05 | Propulsion |
| Barella, Christopher | U.S.A. | Undergrad | SU03, FA03, SP04 | Structures, Launch Vehicle |
| Belotti, Tina | U.S.A. | Undergrad | SP04 | Power |
| Bierbower, Brennen | U.S.A. | Undergrad | SP03 | Power |
| Brandt, Christopher | U.S.A. | Undergrad | SP03 | Scientific Instruments |
| Brossman, John | U.S.A. | Undergrad | SP04, FA04, SP05 | Magnetic Torquer |
| Brown, Jamie | U.S.A. | Undergrad | FA03, SP04, SU04, FA04, SP05, SU05 | Structures, Guidance Navigation and Control |
| Brown, Kevin | U.S.A. | Undergrad | SP04 | Communications |
| Berridge, Robyn | U.S.A. | Undergrad | SP03 | GPS |
| Belotti, Christina | U.S.A. | Undergrad | FA03 | Power |
| Bessette, Chris | U.S.A. | Undergrad | FA03, SP04 | Systems Integration |
| Butts, Donald | U.S.A. | Undergrad | SP04 | Guidance Navigation and Control |
| Caldwell, Mike | U.S.A. | Undergrad | SU04 | C&DH |
| Carey, Ryan | U.S.A. | Undergrad | FA03, SP04 | Power |
| Chadwick, William | U.S.A. | Undergrad | SP03 | Guidance Navigation and Control |
| Chianese, Silvio | U.S.A. | Undergrad | SP03 | Propulsion |
| Cipollo, Peter | U.S.A. | Undergrad/Grad | FA03, SP04, SU04, FA04, SP05 | Structures, Launch Vehicle |

| | | | | |
|---|---|---|---|---|
| Cochrane, Cory | U.S.A. | Undergrad | SP04 | Guidance Navigation and Control |
| Collins, Dillon | U.S.A. | Undergrad | FA04, SP05, SU05 | Command and Data Handling |
| Craychee, Tim | U.S.A. | Undergrad | SP03 | Structures, Launch Vehicle |
| Crisamore, Josh | U.S.A. | Undergrad | SP04 | Software |
| Dorbrin, Daniel | U.S.A. | Undergrad | SU03 | Power |
| Dulski, Matt | U.S.A. | Undergrad | SP03 | Structures, Launch Vehicle |
| Edwards, Sarah | U.S.A. | Undergrad | SP03 | Guidance Navigation and Control |
| Elton, Nicholas | U.S.A. | Undergrad | SP03 | Scientific Instruments |
| Fakhari, Yasher | U.S.A. | Grad | SU04, FA04, SP05, SU05 | Command and Data Handling |
| Fong, Nhan | U.S.A. | Undergrad | SP03 | Communications |
| Fortin, William | U.S.A. | Undergrad | SP05 | Structures |
| Freeman, Darin | U.S.A. | Undergrad | SP04 | Communications |
| Galley, Gary | U.S.A. | Undergrad | SP04 | Magnetic Torquer |
| Geiple, Joshua | U.S.A. | Undergrad | SP03 | Systems Integration |
| Gerlins, Amanda | U.S.A. | Undergrad | SP03 | Education and Public Outreach |
| Haddad, Michael | U.S.A. | Undergrad | SP03 | Guidance Navigation and Control |
| Hannon, Christine (Leeds University, England) | Italy | Undergrad | SU04 | Thermal |
| Hau, Cheng Yee (Leeds University, England) | U.K. | Undergrad | SU04 | Thermal |
| Hazinski, Lisa | U.S.A. | Undergrad | SP03 | Systems Integration |
| Hermanson, Nathan | U.S.A. | Undergrad | SP04 | Thermal |
| Hur, Phil-Sun | South Korea | Grad | SP03, SU03, FA03 | Guidance Navigation and Control |
| Hoban, Martin | U.S.A. | Undergrad | SP04 | Power |
| Hoffman Marc | U.S.A. | Undergrad | SP03, SU03 | Systems Integration |
| Holmes, Robert (PSU-Mont Alto) | U.S.A. | Undergrad | SP04 | Magnetic Torquer |
| Jakub, Thomus | U.S.A. | Undergrad | SP03 | Guidance Navigation and Control |

| | | | | |
|---|---|---|---|---|
| Juergens, Chris | U.S.A. | Undergrad | SP04 | Communications |
| Jones, Nathan | U.S.A. | Undergrad | SP04 MA | Magnetic Torquer |
| Kelly, Erin | U.S.A. | Undergrad | SP04 | Magnetic Torquer |
| Kissinger, Dean | U.S.A. | Undergrad | FA03 | Power |
| Kong, Will (PSU-Mont Alto) | U.S.A. | Undergrad | SP04 | Magnetic Torquer |
| Krauland, Rick | U.S.A. | Undergrad | FA03 | Magnetic Torquer |
| Larson, Rachel | U.S.A. | Undergrad | SP03, SU03 | Structures/Launch Vehicle |
| Lawrence, Doug | U.S.A. | Undergrad | SP04 | Communications |
| Lehmer, Robert | U.S.A. | Undergrad | SP03 | Power |
| Lin, Kevin (Berkeley University of California) | U.S.A. | Undergrad | SU04 | Communications |
| Majeran, Matthew | U.S.A. | Undergrad | SP03 | Scientific Instruments |
| McDonald, Adam | U.S.A. | Undergrad | SP04 | Thermal |
| McIntyre, Megan | U.S.A. | Undergrad | SP03 | Structures, Launch Vehicle |
| Mendoza, Erika | U.S.A. | Undergrad | SP03, SU03, FA03 | GPS |
| Mesienhelder, Timothy | U.S.A. | Undergrad | SP03 | Guidance Navigation and Control |
| Miller, Brooks | U.S.A. | Undergrad | SP04, FA04, SP05 | AEROSPACE Advisor |
| Miller, Wayne | U.S.A. | Undergrad | SP05 | Command and Data Handling |
| Mistoco, Valérie | France | Grad | SP03, SU03, FA03 SP04, SU04, FA04, SP05, SU05 | Propulsion, Student Deputy Project Manager |
| Munson, Matt | U.S.A. | Undergrad | SP04 MA | Magnetic Torquer |
| Musser, Joe (Mansfield University of Pennsylvania) | U.S.A. | Undergrad | SU04, SU05 | Power |
| Modlin, Eli | U.S.A. | Undergrad | SP04 | Communications |
| Morr, Derek | U.S.A. | Undergrad | SU03 | Communications |
| Navarro, Susana | U.S.A. | Undergrad | SP03 | GPS |
| Ng Chong, Denis | U.S.A. | Undergrad | SP04 | Communications |
| Noga, Dawn | U.S.A. | Undergrad | FA03 | Propulsion |
| Oconnor, Nathan | U.S.A. | Undergrad | SP04 | Communications |
| Ozimek, Marty | U.S.A. | Undergrad | FA03 | Guidance Navigation |

| | | | | |
|---|---|---|---|---|
| | | | | and Control |
| Paradee, Gary (PSU-Mont Alto) | U.S.A. | Undergrad | SP04 | Magnetic Torquer |
| Park, Young | South Korean | Undergrad | FA03 | Structures |
| Patel, Prashant | U.S.A. | Undergrad | SP04 | Magnetic Torquer |
| Penagaricano, Oier | Spain | Undergrad | FA03, SP04 | Guidance Navigation and Control |
| Petitprez, Dimitry (IUT of Béthune) | France | Undergrad | SP04, SU04 | Structures |
| Pillitteri, Nicholas | U.S.A. | Undergrad | FA04, SP05 | Communications |
| Polak, Ludovic (IUT of Béthune) | France | Undergrad | SP04, SU04 | Structures |
| Rajab, Sayed-Khaled | U.S.A. | Undergrad | SP03, SP04 | GPS |
| Reich, Alexander | U.S.A. | Undergrad | FA03, SP04 | Systems Integration, Thermal |
| Riccobono, Thomas | U.S.A. | Undergrad | SU05 | Command and Data Handling |
| Rodgers, Rhianna | U.S.A. | Undergrad | SP03 | Communications |
| Rodriguez, Marcello | U.S.A. | Undergrad | SP05 | Scientific Instruments |
| Rosenberg, Becky | U.S.A. | Undergrad | FA03, SP04 | Guidance Navigation and Control |
| Ryll, Bradford | U.S.A. | Undergrad | SP04 | Guidance Navigation and Control |
| Safko, Michael | U.S.A. | Undergrad | SP03, SU03, FA03, SP04 | GPS, Thermal |
| Salerno, Adam | U.S.A. | Undergrad | FA03 | Magnetic Torquer |
| Sams, Matt | U.S.A. | Undergrad | FA03 | Magnetic Torquer |
| | | | | |
| Siegel, Robert | U.S.A. | Grad | SP03, SU03, FA03, SP04 | Scientific Instruments |
| Simmons, Matthew | U.S.A. | Undergrad | SP05 | Structures |
| Sorber, Phillip | U.S.A. | Undergrad | SU03 | C&DH |
| Stark, Lisa | U.S.A. | Undergrad | SU05 | Power-Wiring |
| Stempin, Jonathan | France | Undergrad | SP05, SU05 | Propulsion |
| Stephenson, Lyndon | U.S.A. | Undergrad | SP03 | GPS |
| Surrusco, Brendan | U.S.A. | Grad | SP03, SU03, FA03, SP04, SU04, FA04, SP05 | Student project manager, C&DH, Communications |

| | | | | |
|---|---|---|---|---|
| Speal, Emilia | U.S.A. | Undergrad | SP04 | Propulsion |
| Thakker, Joel | U.S.A. | Undergrad | SP04 | Thermal |
| Thomas, Anju | U.S.A. | Undergrad | FA03, SP04, FA04 | Structures/Launch Vehicle |
| Thomas, Rebecca | U.S.A. | Undergrad | FA03, SP04 | Structures/Launch Vehicle |
| Trudel, Thomas | U.S.A. | Undergrad | SU05 | Propulsion |
| Twedt, Jason (Mansfield University of Pennsylvania) | U.S.A. | Undergrad | SU04 | Structures |
| Vomero, James | U.S.A. | Undergrad | SP04, SU04 | Magnetic Torquer |
| Wagner, Asa | U.S.A. | Undergrad | FA03 | Magnetic Torquer |
| Wagner, Jeff | U.S.A. | Undergrad | SP04, FA04, SP05 | Power, Communications |
| Wallo, Eric | U.S.A. | Undergrad | SP03, SU03 | Power |
| Walter, Frank | U.S.A. | Undergrad | SP03 | Guidance Navigation and Control |
| Wyland, Michael | U.S.A. | Undergrad | SP03 | Scientific Instruments |
| Youanof, Nicolette | U.S.A. | Undergrad | FA03, SP04 | Systems Integration |
| Yucha, Brad | U.S.A. | Undergrad | SP04 | Communications |
| Yurasko, Rebecca | U.S.A. | Undergrad | SP03 | Education and Public Outreach |

## 5. PUBLICATIONS

None.

## 6. INTERACTIONS/TRANSACTIONS

### 6.1 Participation/presentations at meetings, conferences, etc.

Three papers have been presented at national conferences and meetings:

Hur, P.-S., Melton, R.G., and Spencer, D.B., "Meeting Science Requirements For Attitude Determination And Control In A Low-Power, Spinning Nanosatellite," International Astronautics Congress, Vancouver, Canada, Oct. 4–8, 2004, paper IAC-04-IAF-A.4.05.

Surrusco, Brendan S., Sven G. Bilén, and Charles L. Croskey, "A low-cost, powerful flight computer design including Linux and IP technology for the low-Earth-orbiting Local Ionospheric Measurements Satellite," AIAA Space 2004 Conference and Exhibit, San Diego, California, 28–30 Sept. 2004.

Bilén, S. G., "Student Satellite Projects: The LionSat Experience," NASA Mid-Atlantic Regional Space Grant Conference, Newark, DE, 22–24 September 2004.

#### 6.1.1 Chronology of Outreach Activities during Performance Period

2 April 2005

*Space Day*

The annual event, Space Day at Penn State, was again organized with the sponsorship of the Pennsylvania Space Grant Consortium. Children enjoyed building hand-launched rockets, string guided balloon rockets, and robots made from packing peanuts at our booth. Older guests were able to view our exhibits on the LionSat mission and satellite design.

### 6.2 Consultative and advisory functions

None

### 6.3 Transitions

None

## 7. NEW DISCOVERIES

None.

## 8. HONORS/AWARDS

Honorable mention in 12th Annual Frank J. Redd Student Competition, Logan, UT Aug. 2004 for "An Electrically Actuated Pin-Puller for Space Application using Nickel-Titanium Memory Alloy," Peter M. Cipollo, Brendan S. Surrusco

## 9. APPENDIX A

The LionSat material presented at the University Nanosat Program's Flight Competition Review (8–9 January 2005) is attached as Appendix A.




# Local Ionospheric Measurements Satellite Flight Competition Review


*The Pennsylvania State University*

**University Nanosat-3 Program**
43rd AIAA Aerospace Science Meeting and Exhibit
9 January 2004
Reno, NV

PENNSTATE

## LionSat Program Objectives


### Mission Statement

The LionSat mission will investigate the local ambient and perturbed plasma environments surrounding a small satellite in the Earth's ionosphere. LionSat will measure the ambient plasma environment and the satellite's ram and wake regions using a novel hybrid plasma probe instrument. LionSat will test a miniature RF ion thruster system that will augment the satellite spin, which is necessary for mapping the plasma environment surrounding the satellite.

### Technology Demonstration

- LionSat will demonstrate the Hybrid Plasma Probe as a plasma diagnostic instrument.
- LionSat will also test *in situ* a miniature RF Ion Thruster as a satellite spin control device.

### Science Mission Goals

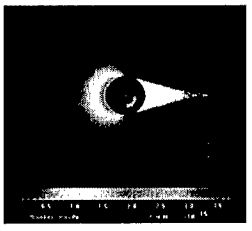
*Primary Objectives:*

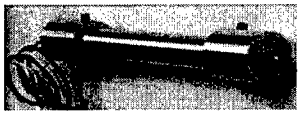
- P1. To map the ram and wake plasma structure surrounding a small satellite
- P2. To collect data on ionospheric plasma in a variety of geophysically interesting locations in low Earth orbit
- P3. To test, on orbit, a miniature RF ion thruster

*Secondary Objective:*

- S1. To test IP communications for uplink and downlink to a spacecraft in low Earth orbit

# Relevance to AF and NASA





- Ionospheric measurements
  - Ambient
  - Local disturbed environment surrounding spacecraft
- Advanced scientific instrumentation
- Deployable structure
- Small mechanisms
- Multifunctional applications

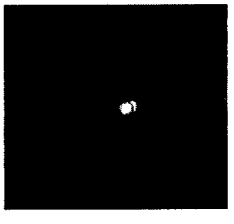

Cipollo, P. M., B. S. Surrusco, and S. G. Bilén, "An Electrically Actuated Pin-Puller for Space Application using Nickel-Titanium Memory Alloy," 18th Annual, AIAA/Utah State University Conference on Small Satellites, 9–12 August 2004.

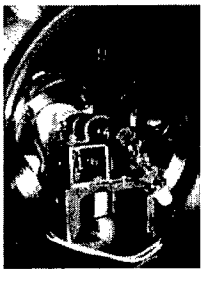
Mistoco, V. F., R. D. Siegel, B. S. Surrusco, E. Medoza, and S. G. Bilén, "Design of the Local Ionospheric Measurements Satellite," 17th Annual, AIAA/Utah State University Conference on Small Satellites, 11–14 August 2003.

Siegel, R. D., IV, Design of a Hybrid Plasma Probe System, M.S. Thesis, Electrical Engineering Dept., Penn State Univ., University Park, PA, May 2004.




# Relevance to AF and NASA





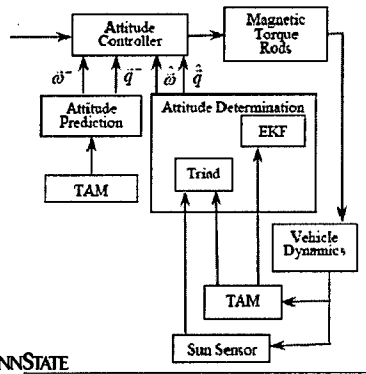
- Innovative propulsion technology for
  - Nano/microspacecraft
  - Constellation flight programs (e.g., Con-X)


Mistoco, V. F. M., S. G. Bilén, and M. M. Micci, "Development and chamber testing of a miniature radio-frequency ion thruster for microspacecraft," 40th AIAA/ASME/ASEE Joint Propulsion Conference, Ft. Lauderdale, FL, 11–14 July 2004

# Relevance to AF and NASA

LionSat

Torque rod with MEMS accelerometer




- Sensors and actuators for guidance, navigation, and control
- Attitude determination and control algorithms


Hur, P.-S., Melton, R.G., and Spencer, D.B., "Attitude Determination and Control of a Nanosatellite Using Geomagnetic Field Data and Sun Sensors," AAS/AIAA Spaceflight Mechanics Meeting, Feb. 8–12, 2004, Maui, Hawaii, paper AAS 04-144.

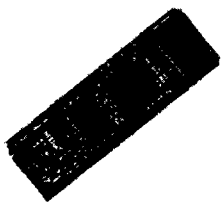
Hur, P.-S., Melton, R.G., and Spencer, D.B., "Attitude Determination and Control for LionSat," 6th International Conference on Dynamics and Control of Systems and Structures in Space, Riomaggiore, Italy, July 18–22, 2004.

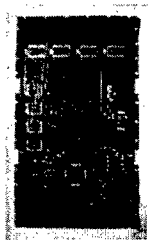
Hur, P.-S., Melton, R.G., and Spencer, D.B., "Meeting Science Requirements For Attitude Determination And Control In A Low-Power, Spinning Nanosatellite," International Astronautics Congress, Vancouver, Canada, Oct. 4–8, 2004, paper IAC-04-IAF-A.4.05.

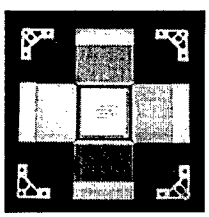



# Relevance to AF and NASA

LionSat



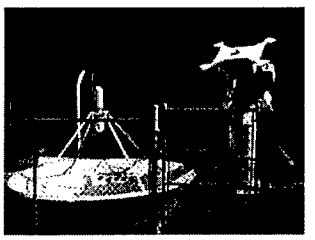




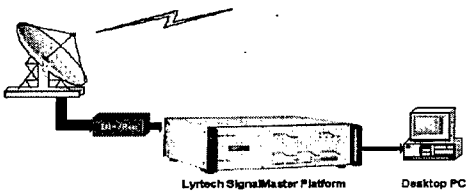
- Electronics for command and data handling
- Incorporation of COTS parts
- Radiation tolerant
- Uses COTS Linux software OS


Surrusco, Brendan S., Sven G. Bilén, and Charles L. Croskey, "A low-cost, powerful flight computer design including Linux and IP technology for the low-Earth-orbiting Local Ionospheric Measurements Satellite," AIAA Space 2004 Conference and Exhibit, San Diego, California, 28–30 Sept. 2004.

# Relevance to AF and NASA



- Space-to-ground communications technology
  - TCP/IP over space-ground and GSE links
  - Software-defined radio ground station



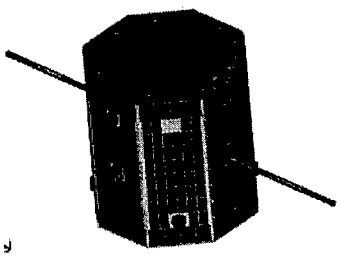

O'Connor, N. F., B. S. Sumusco, C. L. Croskey, and S. G. Bilén, "Software-Defined Radio Ground Station for Internet-Protocol Communications to a Low Earth Orbit Nanosatellite," NASA Fourth Space Internet Workshop, Hanover, MD, 8–10 June 2004.

Sumusco, Brendan, Robert D. Siegel, Phillip M. Sorber, Derek V. Morr, Nathan F. O'Connor, Charles L. Croskey, Sven G. Bilén, and Jason A. Soloff, "Mission planning for employing internet protocol (IP) communications on the Local Ionospheric Measurements Satellite (LionSat)," NASA Third Space Internet Workshop, Cleveland, OH, 4–6 June 2003.

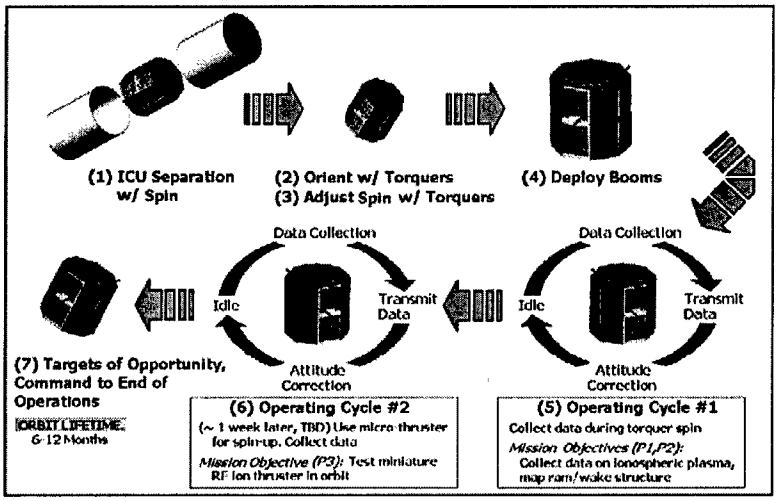


# Spacecraft Technical Data

- Orbit
  - Low Earth orbit—Shuttle mission in 2006
  - 6 months to 1 year lifetime
- Dimensions
  - Diameter: 18.25 inches
  - Length: 18.5 inches
  - Shape: Octagon
- Mass Budget
  - 30 kg maximum
- Power Budget
  - 26.2 W
  - 12–19 V bus depending on load



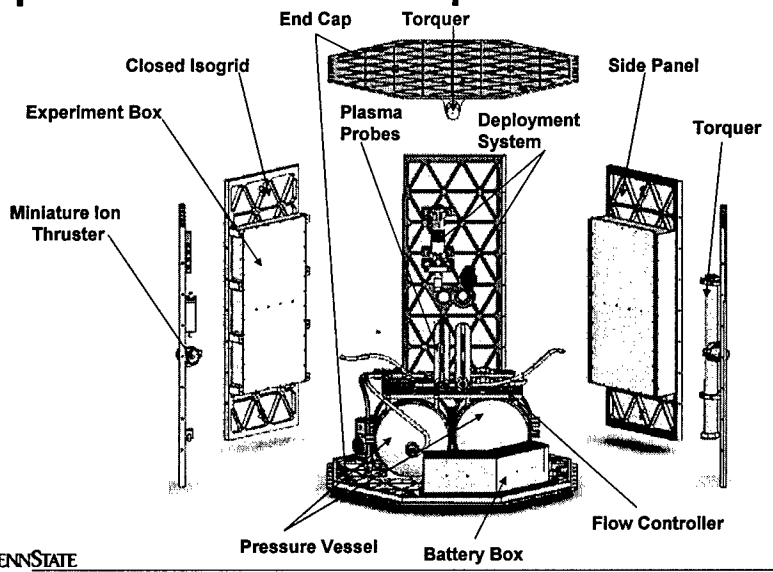
# Mission Timeline




LionSat



# Spacecraft Overview: Exploded View




LionSat

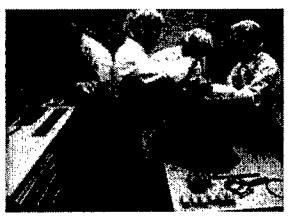
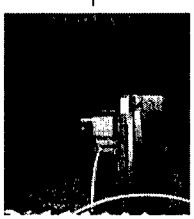
## Protoflight Unit Status

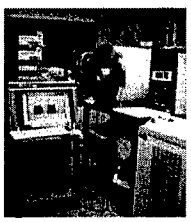
- All systems prototyped, many flight systems produced
- Integration and testing are underway
- All required testing resources available
- Delivery expected by July 2005—existing management structure in place till delivery



## Preparation for Flight

- Testing resources at PSU
  - Cleanroom
  - Anechoic chamber
  - Vibration Tables
  - Thermal/Vacuum facilities



# Safety and Additional Features Requirements


- All NS-3 safety requirements met
  - Structure has minimum worst-case margin of safety 0.54
    - FEA performed
    - Hand analysis with *Isogrid Design Handbook*
  - Solar cell/battery return disconnect on Lightband
  - Solar cell-to-battery inhibit
  - Spacecraft structure has 1-MΩ resistance to electronics ground
  - Continuous conductive path between all major structural components and ICU
  - Battery boxes manufactured to required safety specifications
- Additional features
  - EMI reduction via twisted pairing, shielded boxes, isolated ground/power planes
  - Radiation pre-screened parts used whenever possible
  - Rad-hard FPGA for communication on flight computer
  - Electronic fuses on all systems—1-mA sensitivity/15-μs response/auto reset



# Student Participation


- Student involvement
  - More than 100 university students (first year to graduate) have been involved with LionSat
- Guided educational involvement
  - Several M.S. and B.S. theses
  - Many independent study projects
  - Many "subcontracted" capstone design projects
- Resource for a number of other classes
  - Aerospace capstone course, first-year aero seminar, satellite communications course

# Student Participation


- LionSat team attendance and participation
  - LionSat team has attended all NS-3 events
  - LionSat team has provided all required data packages on time throughout program
  - LionSat has presented at many conferences and has submitted journal articles
- Outreach
  - K–12, NASA Enterprise schools, Pennsylvania's Space Days, professional conferences

## 10. APPENDIX B

The LionSat poster presented at the University Nanosat Program's Flight Competition Review (8–9 January 2005) is attached as Appendix B.

PENNSTATE

# Local Ionospheric Measurements Satellite (LionSat)

LionSat

## LionSat Mission and Operations

### Mission Statement

The LionSat mission will investigate the local ambient and perturbed plasma environments surrounding a small satellite in the Earth's ionosphere. LionSat will measure the ambient plasma environment and the satellite's ram and wake regions using a novel hybrid plasma probe instrument. LionSat will test a miniature RF ion thruster system that will augment the satellite spin, which is necessary for mapping the plasma environment surrounding the satellite.

### Technology Demonstration

- LionSat will demonstrate the Hybrid Plasma Probe as a plasma diagnostic instrument
- LionSat will also test *in situ* a miniature RF Ion Thruster as a satellite spin control device

### Science Mission Goals

***Primary Objectives:***

- P1. To map the ram and wake plasma structure surrounding a small satellite
- P2. To collect data on ionospheric plasma in a variety of geophysically interesting locations in low Earth orbit
- P3. To test, on orbit, a miniature RF ion thruster

***Secondary Objective:***

- S1. To test IP communications for uplink and downlink to a spacecraft in low Earth orbit

### Spacecraft Technical Data

***Orbit:***

- Low Earth orbit—Shuttle mission in 2006
- 6 months to 1 year lifetime

***Dimensions:***

- Diameter: 18.25 inches
- Length: 18.5 inches
- Shape: Octagon

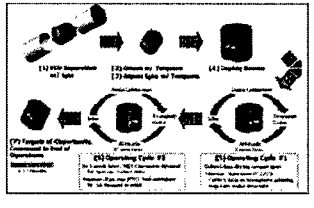
***Mass budget:***

- 30 kg maximum

***Power budget:***

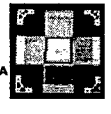
- 26.2 W
- 12–19 V bus depending on load

### Mission Profile



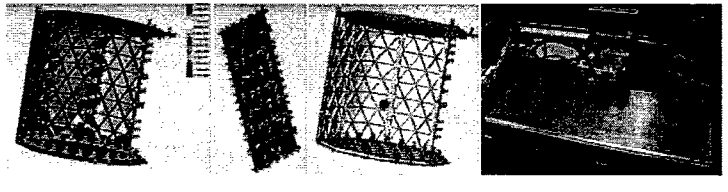
## Command and Data Handling

Rad-hard FPGA



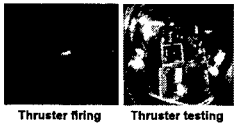
SA-1110 running Linux

## Structural Integrity Analysis and Testing

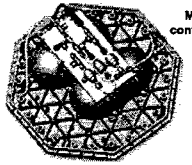




## Miniature RF Ion Thruster



Thruster firing  Thruster testing

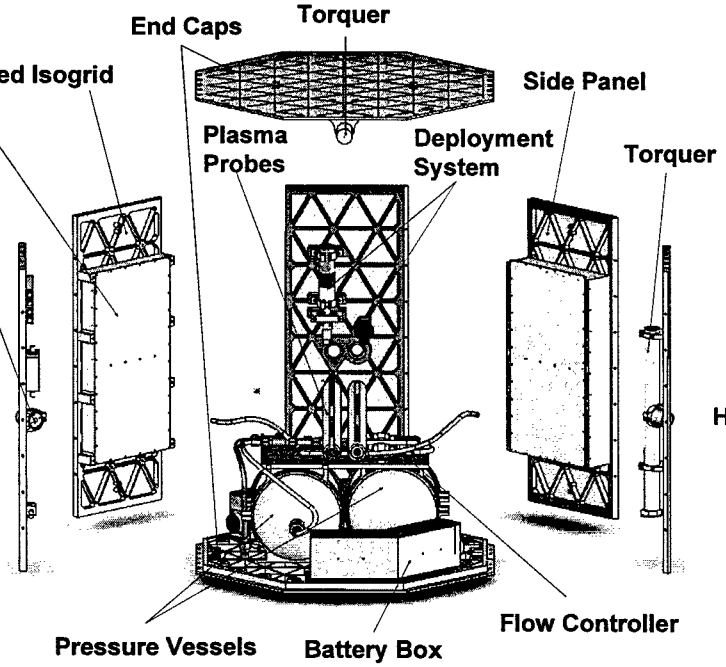


MRIT flow control system

## Communications

Transmitter

TCP/IP over space-ground and GSE links
Software-defined radio ground station




## Spacecraft Overview: Exploded View

## Student Participation

***Student involvement:***

- More than 100 university students (first year to graduate) have been involved with LionSat

***Guided educational involvement:***

- Several M.S. and B.S. theses
- Many independent study projects
- Many "subcontracted" capstone design projects

***Resource for a number of other classes:***

- Aerospace capstone course, first-year aero seminar, satellite communications course

***LionSat team attendance and participation:***

- LionSat team has attended all NS-3 events
- LionSat team has provided all required data packages on time throughout program
- LionSat has presented at many conferences and has submitted journal articles

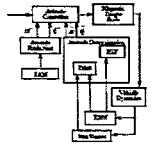
***Outreach:***

- K-12, NASA Enterprise schools, Pennsylvania's Space Days, professional conferences

## GNC

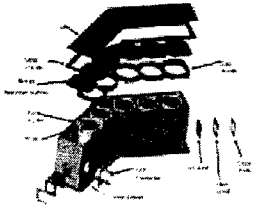
Custom torque rods with MEMS accelerometer

3-axis magnetometer

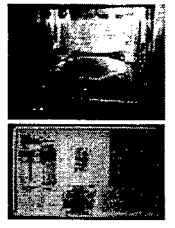


New control algorithms

## Power



Battery box design



Space Rated Solar Cells

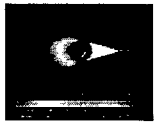
## Hybrid Plasma Probe

***Sensors:***

- Swept Bias Langmuir Probe (SBLP) mode yields electron and ion density, electron temperature, and spacecraft potential
- Fixed Bias Langmuir Probe (FBLP) mode yields fast relative electron or ion density
- Plasma Frequency Probe (PFP) mode provides fast absolute electron density measurements
- Fast Temperature Probe (FTP) mode yields fast, relative electron temperature measurement

***Booms:***

- Two 42-cm aluminum booms extend from center of LionSat into orbit plane using rigid telescoping method
- Each boom contains 2 sensors surrounded by guard regions



Neutral environment surrounding LionSat at 400 km and 7.6 km/s satellite velocity. The orbital plane coincides with the plane of the image. Boom middles rotate through ram and wake while ends remain in ambient environment.

Two booms with two sensors per boom

Pin puller for boom deployment system

## Integration and Test Resources Available

Cleanroom | Cryo Oven | Vibration Test | Thermal-Vac | Anechoic Chamber

PENNSTATE CSRP

LionSat can also rely on resources available to projects under the auspices of Penn State's CSRP